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Applying IUCN Red List criteria at a small regional level: A test case with butterflies in Flanders (north Belgium)

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ABSTRACT

Red Lists are used to assess the extinction risk of species based on quantitative IUCN criteria. For the compilation of a new Red List of butterflies in Flanders (north Belgium), we collated ca 800,000 distribution records and applied the IUCN Red List criteria to this small region (ca 135,00 km^2). We also explored the effect of spatial resolution on the outcome of the Red List assessment by alternatively using 1×1 km^2 and 5×5 km^2 grid cells for geographic range size and trend calculations. We determined conservation hot spots in Flanders based on the Red List status of the species composition in each grid cell. The new Red List classified 20 butterflies (out of 68 resident species) as *Regionally Extinct*, six as *Critically Endangered*, five as *Endangered*, seven as *Vulnerable* and seven as *Near Threatened*. The remaining 23 species were classified as *Least Concern*. Using coarse instead of fine grain grid cells would have classified ten species in a lower Red List category. Compared with the previous Red List, nine species were classified in a lower and 12 in a higher threat category. In total, 218 1×1 km^2 grid cells were considered as (very) high butterfly conservation priority sites. The application of the new IUCN criteria in a small region such as Flanders resulted in a Red List that offered challenging opportunities for the conservation of butterflies in particular and biodiversity in general.

1. Introduction

Red Lists assess the extinction risk of species (Mace et al., 2008) and are often used in conservation planning (Keller and Bollmann, 2004; Miller et al., 2006). In the past, Red Lists were usually compiled using subjective (''expert opinion'') and/or qualitative criteria (Mace and Collar, 1995; Mace and Lande, 1991). Already in 1991, the International Union for Conservation of Nature (IUCN) agreed upon the use of quantitative criteria for the classification of species in threat categories on a global level (Mace and Lande, 1991). These criteria were, however, repeatedly revised and eventually adopted by the IUCN Council in 2000 (IUCN, 2001). In 2003, these criteria were adapted to the regional (non-global) level (Gärdenfors et al., 2001; IUCN, 2003). We recently adopted the IUCN criteria in Flanders (Maes et al., 2011), one of the three administrative regions of Belgium, and tested how they could be applied in this small geographical region (ca 13,500 km^2). The regional Flemish government is responsible for most aspects of nature conservation policy and it is, therefore, more appropriate to compile a regional Flemish Red List than to assess species on a federal Belgian level.

Butterflies are often used as indicators of both environmental quality and biodiversity in general (Brereton et al., 2011). Since they are useful early warning organisms and appealing to the public, butterflies are suitable ambassadors for conservation actions and policy making (Fleishman and Murphy, 2009). Especially in regions under high human pressure, butterflies recently declined strongly and many species became regionally extinct (The Netherlands – Bos et al., 2006; Wallonia (south Belgium) – Fichefet et al., 2008; UK – Fox et al., 2011). A previous analysis pointed out that Flanders was one of the regions with the highest butterfly diversity loss in Europe (Maes and Van Dyck, 2001). The strong decline in butterfly diversity was explained by the high degree of fragmentation of semi-natural biotopes (caused by building and road construction – Peymen et al., 2005) and by the declining habitat quality due to increased nitrogen deposition (mainly caused by both intensive farming, industry and households – Schneiders et al., 2007). At first, only specialized species of rare and threatened biotopes appeared to be affected, but recently also several of the species previously classified as common generalists showed equally strong declines in Flanders and in The Netherlands (Van Dyck et al., 2009).

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Here, we present one of the first cases of the application of the new IUCN criteria for insects in a relatively small region such as Flanders (north Belgium) (but see Cardoso et al., 2011 and Fitzpatrick et al., 2007), and discuss the applicability to other invertebrate groups and the implications for policy. We compared the present Red List with the previous one by applying the new criteria to the data of the previous Red List (Maes and Van Dyck, 1999). To assess the effect of spatial resolution on the eventual Red List categorization, we also compared the use of fine (i.e., 1×1 km^2) and coarse (i.e., 5×5 km^2) grid cell sizes for calculating species trends and distribution areas. Finally, we determined conservation hotspots by using the threat status of the different species and suggest measures for the conservation and management of butterflies in Flanders.

2. Material and methods

2.1. Study area and data

Since the publication of the previous butterfly atlas in Flanders covering the period 1901–1999 (Maes and Van Dyck, 1999), many new records (e.g., observations, monitoring data, garden butterfly counts, systematic grid cell surveys) have been collected in the period 2001–2010, mostly by citizen-science projects. Recent observations are made by skilled volunteers using an online data submission system (http://waarnemingen.be). Although this online recording system is only in use since 2008, it was responsible for almost 1/3 of all butterfly observations in Flanders. Monitoring data are gathered on about 100 transects since 1991 in Flanders (van Swaay et al., 1997). In 2007, the largest private nature organisation in Flanders (Natuurpunt vzw) started a project in which 19 common butterflies are counted monthly in gardens (Bartels and Vanreusel, 2011). Finally, between 2007 and 2009, skilled volunteers collected semi-quantitative data on all butterfly species in so called systematic grid cell surveys by visiting the different biotope types in a random selection of 585 grid cells of 1×1 km^2 during 1 h. In total, 778,226 records were collated for this analysis of which 64% came from the period 2001–2010 (Table 1).

2.2. The IUCN criteria

The IUCN distinguishes 11 categories for listing species in regional Red Lists (IUCN Standards and Petitions Working Group, 2010). Three categories refer to extinct species: *Extinct* (EX – globally extinct species), *Extinct in the Wild* (EXW – species for which populations are only present in captivity) and *Regionally Extinct* (RE – species that are extinct in the focal region). Five categories are used to classify species in different extinction risk categories: *Critically Endangered* (CR), *Endangered* (EN), *Vulnerable* (VU), *Near Threatened* (NT) and *Least Concern* (LC). The three remaining categories are *Data Deficient* (DD – species for which insufficient data are available to classify them in one of the Red List categories, e.g., cryptic or inconspicuous species), *Not Applicable* (NA – species for which the Red List criteria do not apply, e.g., introduced species) and *Not Evaluated* (NE – species that were not yet evaluated against the Red List criteria, e.g., migrant species). We will refer to Red List species as those species belonging to the categories *Regionally Extinct*, *Critically Endangered*, *Endangered*, *Vulnerable* or *Near Threatened*. Five criteria are used to classify species in the categories *Critically Endangered*, *Endangered* and *Vulnerable* (Mace et al., 2008): (A) population reduction during the last 10 years, (B) geographic range, (C) small population size and decline, (D) very small or restricted population and (E) quantitative analysis of extinction risk (Mace et al., 2008).

2.3. Applying IUCN criteria to Flanders (north Belgium)

For the Red List classification of butterflies in Flanders, we only used IUCN criteria A, B and E. Table 2 gives an overview of the thresholds used to classify species as *Critically Endangered*, *Endangered*, *Vulnerable* or *Near Threatened* in Flanders. Species not assigned to one of these categories were classified as *Least Concern*. If testing against different criteria resulted in different categories, the species was classified in the highest of the obtained threat categories (Mace et al., 2008). IUCN Criteria C and D could not be used because absolute population numbers are not readily available for butterflies and other invertebrates. These criteria are more tailored for long-lived organisms than for other smaller and less conspicuous organisms (e.g., Hallingbäck et al., 1995; Regnier et al., 2009). To correctly compare the new Red List with the previous one, we also applied the method presented here to the data of the previous Red List.

2.3.1. Criterion A2c: population reduction

Since Flanders does not have an extensive butterfly monitoring network as the UK (Botham et al., 2009) or the Netherlands (van Swaay et al., 2008), we were unable to estimate changes in the *number of individuals* during the last 10 years. Instead, we calculated the changes in *distribution area* between the periods 1991–2000 and 2001–2010 by counting the number of 1×1 km^2 grid cells in which a species occurred in each period. Since the second period was much better surveyed than the first period (Table 1), we limited the analysis to the grid cells that were surveyed in both periods and in which at least five species were observed in both periods ($N = 1614$ grid cells – Fig. 1). For each species, we subsequently calculated a relative distribution area per period. Again, to account for the more complete survey in the second period, we divided the number of grid cells by the grid cell sum in each period (20,317 and 23,614 in the period 1991–2000 and 2001–2010, respectively – cf. Desender and Turin, 1989). We subsequently calculated the trend giving the change in distribution area in 1×1 km^2 grid cells between the period 2001–2010 and the period 1991–2000, using the following formula:

$$\text{Trend} = 100 \times \frac{(\text{rel.dist 2001–2010}) - (\text{rel.dist 1991–2000})}{(\text{rel.dist 1991–2000})}$$

To assess the effect of spatial resolution on the classification of species, we also calculated a change in distribution area using the same formula but with a relative distribution based on 5×5 km^2

Table 1
Number of records per record type and the number of surveyed grid cells before and since 2001.

Record type	Before 2001	2001–2010	Total
Occasional observations	214,891	416,711	631,602 (81%)
Butterfly monitoring	65,743	29,877	95,620 (12%)
Garden butterfly counts	–	38,193	38,193 (5%)
Systematic grid cell surveys	–	12,811	12,811 (2%)
Total number of records	280,634 (36%)	497,592 (64%)	778 226
Number of 5×5 km^2 surveyed grid cells	616 (96%)	636 (99%)	638 (99%)
Number of 1×1 km^2 surveyed grid cells	4575 (32%)	9708 (68%)	10,667 (74%)

Table 2
IUCN criteria used to classify butterflies in the different IUCN Red List categories in Flanders. '–': the criterion is not used.

Red List category		Critically endangered	Endangered	Vulnerable	Near threatened
Criterion A2c: Population reduction					
Decline in area of occupancy (AOO)		⩾80%	50–80%	30–50%	20–30%
Criterion B2: Geographic range size AOO		<10 km^2	10–500 km^2	500–2000 km^2	2000–3000 km^2
And at least two of the three subcriteria (a)–(c)					
a	(i) Severely fragmented or				
	(ii) Number of locations	1	2–5	6–10	–
b	(ii) Decline in AOO				
	(iii) Decline in area, extent and/or quality of the habitat				
c	(iv) Extreme fluctuations in the number of mature individuals				
Criterion E: Quantitative analysis of extinction risk (*based on the Climatic Risk Atlas of European butterflies* – Settele et al., 2008)					
Predicted decline in AOO of		–	–	–	⩾95%

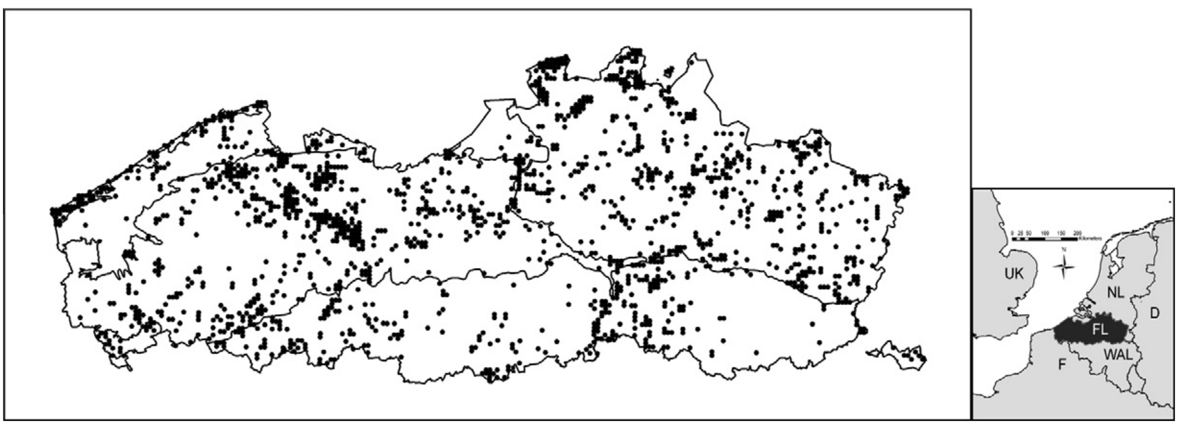

Fig. 1. Grid cells of 1 × 1 km^2 in Flanders used to calculate changes in distribution area between the periods 1991–2000 and 2001–2010. These grid cells were surveyed in both periods and in all grid cells at least five species were observed in both periods. The background shows the five major ecoregions (i.e., regions with similar geological, geomorphological, ground and surface water characteristics).

instead of 1 × 1 km^2 grid cells. Apart from a recent population trend, we also calculated a historical trend by comparing the distribution area in the period 2001–2010 with that in the period 1951–2000. Due to the less accurate mapping in the period 1951–2000, we used grid cells of 5 × 5 km^2 for the historical trend calculation instead of 1 × 1 km^2 grid cells. The 10-year trend for all species using both 1 × 1 km^2 and 5 × 5 km^2 grid cells is given in the Supplementary Appendix A.

2.3.2. Criterion B2: geographic range

We used the number of 1 × 1 km^2 grid cells in which each species was observed in the period 2001–2010 as the area of occupancy (AOO). Additionally, we used subcriterion b(iii) for species of nutrient-poor grasslands and heathlands, two of the most threatened biotopes in Flanders that show a declining habitat quality due to a high pressure of atmospheric nitrogen deposition (Schneiders et al., 2007; Van Landuyt, 2002). Subcriterion c(iv) was used for species with extreme fluctuations in the number of individuals, e.g., *Vanessa atalanta* (a partial migrant in Flanders – see further) and for *Nymphalis polychloros* and *N. antiopa*, two highly mobile species that can be observed in highly variable numbers from year to year. We classified species as *Near Threatened* under criterion B2 if it had an AOO of 2000–3000 km^2 and if two of the three subcriteria were fulfilled or when it had an AOO of less than 2000 km^2 but only one of the three subcriteria of criterion B2 was fulfilled (Mace et al., 2008). When using 5 × 5 km^2 grid cells, the AOO was calculated as the total area of the occupied grid cells 5 × 5 km^2 (e.g., a species occurring in 25 grid cells of 5 × 5 km^2 would have an AOO of 625 km^2).

2.3.3. Criterion E: quantitative analysis indicating the probability of extinction

The distribution of butterflies is relatively well known in Europe (Kudrna, 2002). Recently, European distribution data were used to compile a Climatic Risk Atlas of European Butterflies in which potential climate change induced shifts in distributions were modelled (Settele et al., 2008). We considered species as *Near Threatened* if a decline in distribution area of at least 95% was predicted in Belgium (Table 2 – cf. van Swaay et al., 2011) in a scenario similar to the IPCC A1FI climate change scenario (a mean temperature increase of 4.1 °C in 2080 – Spangenberg et al., 2012).

2.3.4. Downgrading and upgrading of Red List categories

In a first step, regional Red List classifications were carried out using the IUCN criteria described above. A similar approach was used for the new Red List of British butterflies in the UK (Fox et al., 2011) and for the European Red List of butterflies (van Swaay et al., 2011). But, according to the IUCN criteria for regional levels (IUCN, 2003), the resulting IUCN Red List category from this assessment should be downgraded by one category if populations in neighbouring regions can exert a rescue effect on the Flemish populations. Since Flanders is a relatively small region (ca 13,500 km^2) surrounded by regions/countries with a similar butterfly fauna, this rescue effect is possible for a number of species. To take the possible rescue effect into account, we also checked the Red List

status of the species in (one of) the neighbouring regions (the Netherlands – Bos et al., 2006 and Wallonia (south Belgium) – Fichefet et al., 2008). If a species was not threatened (*Least Concern*) in the neighbouring regions or in the region from which the rescue

Table 3
IUCN criteria used to classify butterflies in the new Red List of Flanders (north Belgium).

Regionally extinct (between brackets the last year of observation in Flanders)

Aporia crataegi (1965)	*Coenonympha tullia* (1994)	*Melitaea athalia* (1968)
Argynnis adippe (1947)	*Euphydryas aurinia* (1959)	*Melitaea diamina* (1954)
Argynnis aglaja (1971)	*Heteropterus morpheus* (1995)	*Phengaris teleius* (1980)
Argynnis niobe (1977)	*Hipparchia statilinus* (1902)	*Plebejus idas* (1984)
Boloria euphrosyne (1949)	*Leptidea reali* (probably late 1950s)	*Pyrgus armoricanus* (1952)
Boloria selene (1995)	*Limenitis populi* (1967)	*Spialia sertorius* (1937)
Coenonympha hero (1912)	*Melanargia galathea* (2003)	

	Criterion A2c	Criterion B2	Criterion E	Historical trend	RLC Wal	RLC NL	Rescue effect	Comments
Critically Endangered (CR)								
Melitaea cinxia	NT [20–30%]	**EN** [10–500 km^2, a(i)b(ii,iii)]	–	>50%	(LC)	CR	–	Upgraded (historical decline)
Nymphalis antiopa	LC [<20%]	**CR** [<10 km^2, a(ii)c(iv)]	–	–	EN	RE	–	
Nymphalis polychloros	VU [30–50%]	**EN** [10–500 km^2, b(ii,iii)c(iv)]	–	>50%	LC	CR	–	Upgraded (historical decline)
Phengaris alcon	VU [30–50%]	**EN** [10–500 km^2, a(i)b(ii,iii)	–	>50%	–	EN	–	Upgraded (historical decline)
Pyrgus malvae	LC[(<20%]	**EN** [10–500 km^2, a(i)b(iii)]	NT	>50%	VU	EN	–	Upgraded (historical decline)
Satyrium ilicis	**EN** [50–80%]	**EN** [10–500 km^2, a(i)b(ii,iii)]	–	>50%	(CR)	EN	–	Upgraded (historical decline)
Endangered (EN)								
Apatura iris	VU [30–50%]	**EN** [10–500 km^2, a(i)b(ii)]	–	–	LC	CR	–	
Hesperia comma	NT [20–30%]	**EN** [10–500 km^2, a(i)b(ii,iii)]	–	–	(CR)	EN	–	
Hipparchia semele	LC [<20%]	**EN** [10–500 km^2, a(i)b(iii)]	–	–	(CR)	NT	–	
Lasiommata megera	**EN** [50–80%]	**EN** [10–500 km^2, a(i)b(ii,iii)]	–	>50%	LC	LC	Y	
Plebejus argus	LC [<20%]	**EN** [10–500 km^2, a(i)b(iii)]	–	–	(VU)	NT	–	
Vulnerable (VU)								
Callophrys rubi	LC [<20%]	**EN** [10–500 km^2 km^2, a(i)b(iii)]	–	–	(NT)	LC	Y	Downgraded (rescue effect)
Cyaniris semiargus	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	>50%	NT	(RE)	–	Upgraded (historical decline)
Erynnis tages	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	>50%	NT	CR	–	Upgraded (historical decline)
Lycaena tityrus	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	>50%	LC	VU	–	Upgraded (historical decline)
Satyrium w-album	LC [<20%]	**EN** [10–500 km^2, a(i)b(iii)]	–	–	LC	(CR)	Y	Downgraded (rescue effect)
Thymelicus lineola	**VU** [30–50%]	NT [500–2000 km^2, b(ii,iii)]	–	–	NT	LC	–	
Thymelicus sylvestris	**EN** [50–80%]	**EN** [10–500 km^2, a(i)b(ii,iii)]	–	–	LC	LC	Y	Downgraded (rescue effect)
Near Threatened (NT)								
Aglais urticae	**VU** [30–50%]	NT [2000–3000 km^2, b(ii)]	NT	–	LC	LC	Y	Downgraded (rescue effect)
Carterocephalus palaemon	LC [<20%]	**NT** [10–500 km^2, a(i)]	–	–	(LC)	VU	–	
Cupido minimus	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	–	EN	(RE)	–	
Gonepteryx rhamni	**VU** [30–50%]	NT [2000–3000 km^2, b(iii,iii)]	–	–	LC	LC	Y	Downgraded (rescue effect)
Issoria lathonia	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	–	(LC)	VU	–	
Leptidea sinapis	LC [<20%]	**NT** [10–500 km^2, b(iii)]	–	–	LC	NT	–	
Limenitis camilla	LC [<20%]	**NT** [10–500 km^2, a(i)]	–	–	LC	EN	–	
Least Concern (LC)								
Aglais io	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Anthocharis cardamines	LC [<20%]	LC [2000–3000 km^2]	–	–	LC	LC	Y	
Aphantopus hyperantus	LC [<20%]	LC [500–2000 km^2]	**NT**	–	LC	LC	Y	Downgraded (rescue effect)
Araschnia levana	**NT** (20–30%]	**NT** [500–2000 km^2, b(ii)]	–	–	LC	LC	Y	Downgraded (rescue effect)
Argynnis paphia	LC [<20%]	LC [10–500 km^2]	–	–	LC	(RE)	Y	
Aricia agestis	LC [<20%]	LC [500–2000 km^2]	–	–	LC	NT	–	
Carcharodus alceae	–	LC [10–500 km^2]	–	–	LC	–	Y	
Celastrina argiolus	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Coenonympha pamphilus	LC [<20%]	**NT** [500–2000 km^2, b(iii)]	–	–	LC	LC	Y	Downgraded (rescue effect)
Favonius quercus	LC [<20%]	LC [500–2000 km^2]	–	–	NT	LC	–	
Lycaena phlaeas	LC [<20%]	LC [2000–3000 km^2]	–	–	LC	LC	Y	
Maniola jurtina	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Ochlodes sylvanus	LC [<20%]	LC [500–2000 km^2]	–	–	LC	NT	–	
Papilio machaon	LC [<20%]	LC [2000–3000 km^2]	–	–	LC	LC	Y	
Pararge aegeria	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Pieris brassicae	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Pieris napi	**NT** (20–30%]	LC [>3000 km^2, b(ii)]	–	–	LC	LC	Y	
Pieris rapae	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Polygonia c-album	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Polyommatus icarus	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Pyronia tithonus	LC [<20%]	LC [>3000 km^2]	–	–	LC	LC	Y	
Thecla betulae	LC [<20%]	**NT** [500–2000 km^2, b(iii)]	–	–	LC	(EN)	Y	Downgraded (rescue effect)
Vanessa atalanta	LC [<20%]	LC [>3000 km^2]	–	–	NE	NE	Y	

Criterion A2c, B2 and E represent the IUCN criteria used to compile the Flemish Red List (see Table 2); if a species meets one of the criteria, the resulting Red List category and the criteria are given between square brackets; '–' means that none of the criteria were met; the highest threat category per species is given in bold. If the historical decline is lower than 50% it is indicated with '–'. RLC Wal and RLC NL are the Red List status in Wallonia (south Belgium) and the Netherlands respectively; if the threat status is given between brackets, the distance to the nearest Flemish populations is considered too far to exert a rescue effect from that region or country; '–' means that the species is absent from the region or in the country. The comments indicate whether a species was up- or down-graded to obtain the final Red List category for Flanders. Species names are according to Fauna Europaea (http://www.faunaeur.org/).

is most likely, we downgraded the species by one Red List category according to the IUCN criteria. But, if the species was classified as *Critically Endangered*, *Endangered*, *Vulnerable* or *Near Threatened* in (one of) the neighbouring regions or in the region from which the rescue is most likely, we retained the initially obtained Red List category.

On the other hand, if the historical trend was strongly negative, we upgraded the Red List category of a species with one category. In our case, we arbitrarily used the threshold of a 50% decline in distribution area as a strong historical decline which corresponds with the IUCN criterion A2 for the Red List category *Endangered* (Fox et al., 2011)

2.4. Conservation priority sites

To determine conservation priority sites, we assigned numeric values to the different Red List categories that correspond with the trend in distribution area criterion (criterion A2): *Least Concern* species were assigned a value of 1 (very small extinction risk), *Near Threatened* species a value of 20 (low extinction risk – corresponding with the threshold value of a 20% decline to classify for the *Near Threatened* category), *Vulnerable* species a value of 30, *Endangered* species a value of 50 and *Critically Endangered* species a value of 80 (highest extinction risk). Subsequently, we summed these values to obtain an extinction risk value (ERV) per 1×1 km^2 grid cell and differentiated between grid cells with a very high (i.e., ERV $\geqslant$ 200), a high (ERV 150–199), a low (ERV 100–149) and a very low conservation priority (ERV < 100).

3. Results

Applying the new IUCN criteria and their subcriteria to the 68 resident butterfly species in Flanders resulted in 20 *Regionally Extinct* species, six *Critically Endangered* species, five *Endangered* species and seven *Vulnerable* species (Table 3). A further seven species were considered *Near Threatened* and the remaining 23 species were assessed as *Least Concern*. In total, 66% of the butterfly species in Flanders were considered extinct or threatened. Compared with the neighbouring countries or regions, Flanders and the Netherlands have a similarly high proportion of Red List species (66–68%) while Wallonia and the UK have lower numbers of threatened species (55–59%).

Compared with the previous Red List (but applying the method presented here), a similar percentage (68% vs. 66%) was classified as *Near Threatened* or higher in both the previous and the actual Red List. Twelve species were classified in a higher (i.e., more threatened) Red List category compared to the previous Red List: *Melanargia galathea* (last observation in 2003), *Heteropterus morpheus* (1995), *Boloria selene* (1995) and *Coenonympha tullia* (1994) became *Regionally Extinct*, four species were already classified as *Endangered* in the previous Red List but were now assessed as *Critically Endangered*: *Satyrium ilicis*, *Melitaea cinxia*, *N. polychloros* and *Phengaris alcon* and four, previously *Least Concern* species were now classified as *Endangered* (*Lasiommata megera*), *Vulnerable* (*Thymelicus lineola*) or *Near Threatened* (*Aglais urticae* and *Gonepteryx rhamni*). Nine species were now considered less threatened than in the previous Red List: the previously *Regionally Extinct* *Erynnis tages* (now *Vulnerable*) and *Nymphalis antiopa* (now *Critically Endangered*) re-colonized Flanders in 2002, *Argynnis paphia*, *Coenonympha pamphilus* and *Thecla betulae* used to be *Vulnerable* or *Near Threatened* but are now considered *Least Concern* and four species were classified in a lower Red List category but are still considered threatened: *Lycaena tityrus* and *Satyrium w-album* (lowered from *Critically Endangered* to *Vulnerable*), *Cyaniris semiargus* (lowered from *Endangered* to *Vulnerable*), *Issoria lathonia* (lowered from *Vulnerable* to *Near Threatened*).

Table 4
Percentage decline at 1×1 km^2 and at 5×5 km^2 resolution and the difference between both (calculated as $100 \times [(1 - (5\text{ km}/1\text{ km})]$ – Thomas and Abery, 1995) for declining common and rare species in Flanders.

Species	Utm1 km	Utm5 km	%difference
Common species (occurring in ⩾ 500 1 × 1 km² grid cells)			
Aglais io	−8	−4	50
Araschnia levana	−20	−11	45
Pieris napi	−20	−11	45
Pararge aegeria	−7	−4	43
Pieris rapae	−10	−6	40
Thymelicus lineola	−31	−20	35
Aglais urticae	−48	−31	35
Gonepteryx rhamni	−30	−22	27
Mean			40
Rare species (occurring in < 500 1 × 1 km² grid cells)			
Apatura iris	−46	−22	52
Cupido minimus	−14	−10	29
Melitaea cinxia	−28	−21	25
Thymelicus sylvestris	−53	−45	15
Lasiommata megera	−69	−67	3
Satyrium ilicis	−60	−68	−13
Coenonympha pamphilus	−19	−22	−16
Phengaris alcon	−47	−57	−21
Hesperia comma	−29	−40	−38
Hipparchia semele	−18	−27	−50
Mean			−1

Using 5×5 km^2 grid cells to calculate distribution areas and changes therein would have classified ten species in a lower Red List category: *N. polychloros* would have been classified as *Endangered* instead of *Critically Endangered*, *Hipparchia semele* and *Plebejus argus* as *Vulnerable* instead of *Endangered*, *Callophrys rubi*, *S. w-album*, *T. lineola* and *T. sylvestris as Near Threatened* instead of *Vulnerable* and *Carterocephalus palaemon*, *G. rhamni* and *I. lathonia* as *Least Concern* instead of *Near Threatened*. Table 4 gives the difference in trends when using 5×5 km^2 instead of 1×1 km^2 grid cells. For common species (present in > 500 1×1 km^2 grid cells), the average difference in trend between 1×1 km^2 grid cells and 5×5 km^2 grid cells was 40% (cf. Thomas and Abery, 1995). For rare species (<500 grid cells), however, this difference is no longer consistent and trends can even be stronger using 5×5 km^2 grid cells than when using 1×1 km^2 grid cells. Four species with an opposite trend between 1×1 km^2 and 5×5 km^2 grid cell trend calculation are typical heathland species in Flanders with a very clustered distribution.

In total, 84 grid cells were assessed as very high priority sites for the conservation of butterflies, 134 as high conservation priority sites and a further 332 as low conservation priority sites. Apart from some isolated sites, most of the (very) high conservation priority grid cells are situated in the north eastern part of Flanders and along the coast (Fig. 2). Grid cells with a (very) high conservation priority had, on average, a significantly larger area of Natura2000 sites than low or very low conservation priority sites (ANOVA $F = 260.83$, $p < 0.0001$ – Fig. 3).

4. Discussion

The fine grain Red List in Flanders using the new IUCN criteria revealed that 30% of the 68 indigenous butterfly species are *Regionally Extinct* and a further 36% are either *Critically Endangered*, *Endangered*, *Vulnerable* or *Near Threatened*. The use of 5×5 km^2 grid cells would have classified ten species in a lower Red List category. Compared with the previous Red List, 12 species are more threatened and nine species fared better. Based on the Red List status of the species composition per 1×1 km^2 grid cell, 218 grid

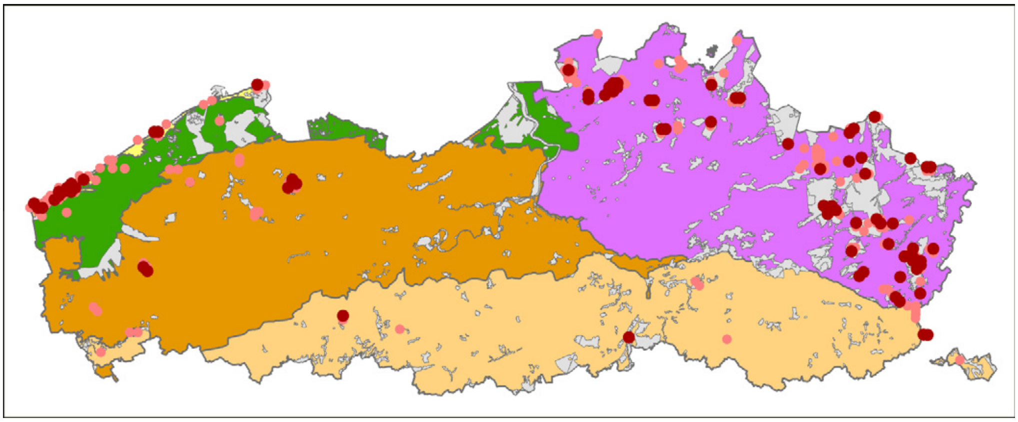

Fig. 2. Conservation priority grid cells in Flanders based on the extinction risk value (ERV) calculated using the Red List status of species in a grid cell: *Critically Endangered* species get a value of 80, *Endangered* species a value of 50, *Vulnerable* species a value of 30, *Near Threatened* species a value of 20 and *Least Concern* species a value of 1. Dark red 1×1 km^2 grid cells have a very high conservation priority (ERV $\geqslant$ 200) and pink grid cells a high conservation priority (ERV 150–199). The areas in grey are Natura2000 sites in Flanders. Ecoregions are given in different colours. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

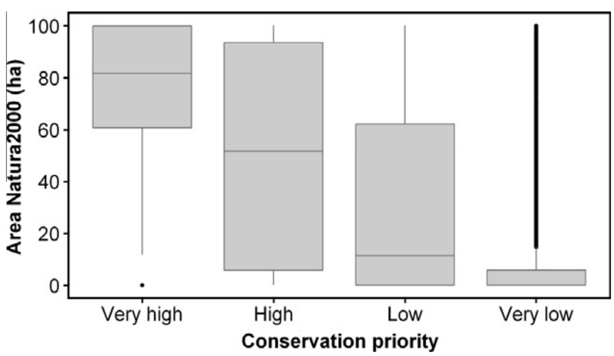

Fig. 3. Average area of Natura2000 sites per 1×1 km^2 grid cell with a very high, a high, a low and a very low conservation priority. The horizontal bar gives the median, the box between the two hinges is the interquartile, the whiskers give the largest/smallest observation that falls within a distance of 1.5 times the box size from the nearest hinge and the black dots are outliers. The conservation priority is calculated using the Red List status of the species composition in each 1×1 km^2 grid cell. A posteriori Tukey tests (all $p < 0.0001$) showed that the average area of Natura2000 sites per 1×1 km^2 grid cell differed significantly among the four conservation priority classes.

cells were determined as high to very high butterfly conservation priority sites.

4.1. Data quality and the use of IUCN criteria in a small region

With over 2000 recorders, almost 10,000 out of 13 500 1×1 km^2 grid cells surveyed and almost 800,000 observations, Flanders is probably amongst the best surveyed regions for butterflies in the world, together with the Netherlands (Bos et al., 2006) and the UK (Asher et al., 2001). In Flanders, the online data submission system http://waarnemingen.be or http://observations.be now "collects" about 80 000 butterfly records per year and allows to collect distribution data at a much finer resolution (usually point locations). The optimal way to calculate population trends is the use of butterfly transects as in the UK (Pollard and Yates, 1993) and in the Netherlands (van Swaay et al., 2008). In Flanders, about 35 butterfly transects were walked yearly between 2001 and 2010 which is not enough for a proper trend calculation for all species (van Strien et al., 1997). Furthermore, the location of the butterfly transects does not include sites with the most threatened species. But for some species, alternative techniques for calculating population trends using detailed and repeated distribution data have been suggested and appeared to be very useful for trend calculations in the absence of monitoring data (van Strien et al., 2010, 2011).

Because of different mapping intensities between a 'historical' and a more recent period, the use of the raw data for calculating changes in distribution area is rarely appropriate. Therefore, relative distributions are often used to calculate changes in distribution area. Most often, a relative distribution is calculated as the ratio between the number of grid cells in which a species was observed and the total number of grid cells surveyed in a given period. A disadvantage of this method, however, is that it does not take spatial differences in mapping into account (i.e., in a first period a different part of a region could have been surveyed than in a second period which makes the relative distributions incomparable). To correct for this, the method could be restricted to those grid cells that were commonly surveyed in both periods. A further disadvantage here, however, is that this adjusted method still does not take differences in mapping intensity into account (i.e., in a first period, observers may have recorded only rare species, while in a second period, all species were mapped). To correct for such differences in mapping intensity, we used the so called grid cell sum in the two periods to calculate relative abundances (cf. Desender and Turin, 1989).

The use of IUCN criteria in a relatively small region such as Flanders proved to be a difficult but feasible exercise. The downgrading process because of a possible rescue effect from neighbouring regions appeared to be the most challenging part of the assessment since it was not as straightforward as the IUCN criteria suggested (Gardenfors, 2001). In our opinion, the mere presence of a population in a neighbouring region is not sufficient to make it a likely migrating propagule (Gärdenfors et al., 2001). We therefore used the Red List category in the neighbouring region and considered a rescue effect unlikely if the species was also threatened in the neighbouring region. For example, *C. palaemon* and *C. rubi* can both be found in the south of the Netherlands and are sufficiently mobile to occasionally exchange individuals with Flemish populations. Both species also occur in neighbouring Wallonia (south Belgium) but populations here are considered too far away (>30–50 km) to expect any rescue effect. But, since *C. palaemon* is classified as *Vulnerable* in the Netherlands, it is unlikely that Flemish populations will be rescued by the Dutch populations. Therefore, we did not use the rescue effect to downgrade the Red List category of this species in Flanders. *C. rubi*, on the other hand, is not threatened in the Netherlands and we assume a possible rescue effect for the Flemish populations. In the case of *C. rubi*, the rescue effect

was, therefore, used to downgrade the threat status by one Red List category. Contrary to the IUCN criteria, we also used the possibility of upgrading a species by one Red List category if a strong decline took place longer than 10 years ago (Maes et al., 2011). Although this 'historical' decline does not necessarily affect the immediate extinction risk of a species, it offers the opportunity to include formerly typical species for a reference situation or period (Keller and Bollmann, 2004; Miller et al., 2006). One of the difficulties when applying the IUCN criteria to butterflies is the 10-year period for which declines should be calculated. Since butterflies, and most other invertebrates, have one or more generations per year and are usually more sensitive to environmental factors, their populations fluctuate much more than long-lived animals (Thomas, 1994) that can more easily lead to extinctions. To differentiate between short term population fluctuations and genuine declines in the distribution and numbers of butterflies and other invertebrates, comparing the short term trend with the historical trend that spans longer time series (e.g., 20–25 years) would be advisable to adjust the trend criterion A of the IUCN (van Swaay et al., 2011). Monitoring data in the UK and in the Netherlands clearly show relatively short term fluctuations in species abundance (e.g., *Celastrina argiolus*). Depending of being on the increase or the decrease side of such fluctuations, species could be classified in different Red List categories even if the long term trend is relatively stable. On the other hand, species that showed their strongest decline longer than 10 years ago, would not qualify for a Red List category if they are not sufficiently rare at present. That is why we, but also the UK (Fox et al., 2011), used both a recent and a 'historical' trend to up- or downgrade the obtained Red List category if appropriate.

Although less long then the Netherlands and the UK, Flanders has a strong tradition in mapping insects. The use of online data submission systems such as http://waarnemingen.be in Flanders will surely increase both the number and the resolution of distribution data. This will enable us the compilation of IUCN Red Lists for some of the other relatively well-mapped insect groups (e.g., dragonflies, grasshoppers, ground beetles) and use them in conservation policy (Cardoso et al., 2011). Although based on a relatively limited amount of data and a smaller number of surveyed grid cells, we demonstrated that the use of other sets of IUCN (sub)criteria than in butterflies (e.g., using extent of occurrence (EOO) instead of area of occupancy (AOO) as a measure of geographic range) resulted in a 'credible' Red List of ladybirds in Flanders (Adriaens et al., in prep.).

4.2. Comparison with previous Red List

Compared with the previous list, three more species were assessed in the present Red List: *V. atalanta*, *Leptidea reali* and *Carcharodus alceae*. *V. atalanta* is observed overwintering yearly since 1990 and is, therefore, now considered as a resident species. *Leptidea sinapis* was recently split into three cryptic species (Dinca et al., 2011) but the (historical) presence of these species in Flanders is unclear. Since *L. reali* occurred in the calcareous regions in the south of the Netherlands until 1958 (Bos et al., 2006), it is likely that *L. reali* was also present in the neighbouring calcareous region in Flanders. *C. alceae* colonized Flanders in 2009 (from neighbouring sites in Wallonia – Fichefet et al., 2008) and now has about 25 well established populations.

The present Red List revealed that the decline of some, both specialist and formerly common, species has not been stopped in Flanders. General reasons for their continuing decline are: (i) the eutrophication and high atmospheric deposition mostly from intensive agriculture leading to a lower habitat quality (loss of food plants, colder microclimate – WallisDeVries and van Swaay, 2006), (ii) the strong decline of nectar sources (WallisDeVries et al., 2010) and (iii) a lowered exchange of individuals among populations in an increasingly fragmented Flemish landscape (Van Dyck et al., 2009).

Out of the nine species that became less threatened, five of them are fairly mobile and probably benefited from a relatively warm period during the last 10 years (Klok and Tank, 2009) to colonize suitable sites. For four less mobile species (*E. tages*, *L. tityrus*, *S. w-album* and *T. betulae*) local species action plans and a more directed search method resulted in a lower Red List status. Especially for *T. betulae* and *S. w-album*, the previous extinction risk and consequent Red List status might have been overestimated because the adult butterflies are difficult to observe. Using specific observation methods (i.e., searching for overwintering eggs on Blackthorn *Prunus spinosa* for *T. betulae* and inspecting tops of Elm trees *Ulmus* sp. with binoculars for *S. w-album*), we now have a much better idea of the distribution area of both species. This enabled us to assign them to a more appropriate category in the present Red List.

4.3. Spatial resolution

Using 5×5 km^2 instead of 1×1 km^2 grid cells would have resulted in 42 instead of 45 Red List species. The use of coarse resolution grid cells is unable to detect declines or losses of 1×1 km^2 grid cells within a 5×5 km^2 grid cell (Cowley et al., 1999; Thomas and Abery, 1995). Additionally, the use of coarse grid cells is believed to strongly overestimate the area of occupancy of species (van Swaay et al., 2011). Here, we showed that this is the case for common and widespread species (Table 4), but that this is not necessarily true for rare species with a clustered distribution pattern. It is, therefore, not appropriate to suppose that trends are equally overestimated by a same percentage (35% as suggested by Thomas and Abery, 1995) for all species when relatively coarse grained grid cells are used. Whenever possible, we therefore recommend the use of the smallest available scale to calculate distribution areas and trends (e.g., 1×1 km^2 or smaller).

4.4. Butterfly and biodiversity conservation and policy

Red Lists are widely recognized as important tools for conservation as they help to prioritize species conservation (Miller et al., 2006). In this vein, the new Red List of butterflies will be an important tool for future conservation policy at the regional Flemish level. As butterflies are increasingly used to inform conservation policy in different European countries, this new information will also serve to explore wider patterns of changes in the butterfly fauna within Europe (van Swaay et al., 2011). Databases used for such analyses are good examples of the significance of citizen-science projects within the context of conservation (Schmeller et al., 2009; Snäll et al., 2011).

However, the translation of different Red List categories into species action plans may also require other sources of important information. Although the factors causing general declines in butterflies are fairly well known (see above), the understanding of the mechanisms behind these patterns requires detailed and additional research. Policy makers tend to give a higher priority to the most endangered species but there is controversy about giving priority to cost-effective actions or focusing on the most endangered species (Wilson et al., 2011). It may indeed be more successful and cost-effective if we start conservation programs long before organisms (and their biotopes) fall within the most threatened Red List categories. The observation that several widespread species declined significantly during the last decennium in Flanders and in the Netherlands (Van Dyck et al., 2009) requires a different approach for conservation planning than classical species action plans (e.g., a relatively widespread but strongly declining species such as *G. rhamni* vs. a localised habitat specialist such as *Phengaris alcon* – Maes et al., 2004). This information should be integrated in

several more holistic biodiversity programs to restore different ecological resources at different scales (habitat, biotope and landscape) both within nature reserves but also across the wider landscape (functional connectivity) outside nature reserves. Although such programs do not necessarily aim to restore the conditions of single species, the information on the resource-based habitat profiles of individual species may help to develop such approaches (Dennis et al., 2006).

The grid cells with the highest conservation priority sites for butterflies show a very clustered pattern with concentrations in the coastal dune ecoregion in the west and the Campine ecoregion in the northeast of Flanders (Fig. 2). Both ecoregions still have remnants of semi-natural sites with dry and wet heathlands (with typical and threatened species such as *Hesperia comma*, *H. semele*, *Phengaris alcon* (Maes et al., 2004), *P. argus* and *S. ilicis*) and nutrient-poor grasslands (with the threatened species *M. cinxia* and *I. lathonia*). The few grid cells with a high conservation priority outside the coastal dune and the Campine ecoregion have relatively large areas of deciduous forests with typical and threatened species such as *Apatura iris*, *A. paphia*, *Limenitis camilla* and *N. antiopa*. Additionally, grid cells with the highest conservation priority for butterflies in Flanders had a significantly higher area of Natura2000 sites (Fig. 3). Since there are currently no butterflies present in Flanders that are listed in the annexes of the Habitat Directive, the Natura2000 sites in Flanders were designated for the presence of biotope types of Annex I of the Habitat Directive or other listed organisms such as amphibians, the Stag beetle (Thomaes et al., 2008) and birds of the Bird Directive. Despite their designation for threatened biotopes and other organisms of European interest, the Natura2000 legislation should also be significant for the conservation of butterflies in Flanders (cf. Klorvuttimontara et al., 2011; Maes et al., 2005; Tushabe et al., 2006). Our analyses indeed suggest a large potential of the Natura2000 sites, but integrating specific needs of different regionally threatened butterfly species into the management plans would require further consideration (Louette et al., 2011).

For Flanders, we are only at the very beginning of developing sound biodiversity policies outside nature reserves, but the success will strongly impact on the extent to which European and international biodiversity targets will be met by 2020. Only a general improvement of landscape quality in both anthropogenic (including agricultural land) and semi-natural landscapes can help to sustainably recover butterfly diversity in a strongly degraded environment. To do so, specific programs need to be developed to restore essential ecological resources (consumables and conditions) across the landscape matrix (Shreeve and Dennis, 2011). Additionally, the more traditional approach of specific species action programs in nature reserves and other protected areas need further intensification. This can be illustrated by the ongoing decline of habitat specialist species such as *H. semele* in many NW European countries (van Strien et al., 2011).

Although Flanders was already one of the worst case scenarios for butterfly diversity loss in Europe (Maes and Van Dyck, 2001), we observed that some species (among which formerly common ones) have declined even further. Only a couple of (very) mobile species expanded their range and are now faring better. To halt the further loss of biodiversity in Flanders, we argue that the inclusion of butterflies into a more general biodiversity conservation action plan, would add complementary information to the often biotope focused policy and management, a strategy that also holds for many other regions or countries elsewhere in Europe (Maes and Van Dyck, 2005).

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2011.11.021.

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